International Journal of Yoga, Physiotherapy and Physical Education
www.sportsjournal.in
ISSN: 2456-5067
Received: 01-06-2025, Accepted: 01-07-2025, Published: 16-08-2025
Volume 10, Issue 3, 2025, Page No. 35-39

Individual and combined effect of plyometric and circuit training on bmi, resting heart rate, and VO_2 Max of adolescent athletes

Manish Acharjee
Department of Physical Education, Swarnim Gujarat Sports University, Gujarat, India.

Abstract
This study examined the individual and combined effects of plyometric and circuit training on body mass index (BMI), resting heart rate (RHR), and maximal oxygen uptake (VO_2 Max) in adolescent athletes. A total of 120 athletes aged 16–18 years were randomly assigned to plyometric, circuit, combined plyometric–circuit, and control groups (n = 30 each). The experimental groups trained three times per week for two weeks, while the control group maintained regular sports practice. BMI, RHR, and VO_2 Max were assessed before and after the intervention using standardized anthropometric, physiological, and aerobic testing protocols. Analysis of covariance (ANCOVA), controlling for pre-test scores, revealed significant group effects for BMI ($p < .001$, $\eta^2 = .275$), RHR ($p = .019$, $\eta^2 = .088$), and VO_2 Max ($p = .001$, $\eta^2 = .291$). Post hoc comparisons showed that combined training resulted in the greatest reduction in BMI, significantly outperforming plyometric, circuit, and control groups. Plyometric training produced the largest reduction in RHR compared to combined training, indicating enhanced cardiovascular efficiency. Circuit and combined training led to greater VO_2 Max improvements than plyometric training, with the combined group showing a slight, non-significant advantage. These results highlight that training modality selection should align with specific physiological goals—combined training is most effective for improving body composition and aerobic capacity, while plyometric training is optimal for lowering resting heart rate. The findings provide evidence-based guidance for designing targeted, age-appropriate conditioning programs to enhance health and performance in adolescent athletes.

Keywords: Resting heart rate, body mass index, plyometrics training, circuit training, vo_2 max, adolescent athletes

Introduction

Adolescent athletes' health, performance, and ability to avoid injuries are all directly impacted by their level of physical fitness, especially their aerobic capacity. Because it increases endurance and tolerance to training stress, elevated maximum oxygen uptake (VO_2 max) has been demonstrated to lower the risk of in-season illness and injury in young athletes [1]. Additionally, aerobic capacity is positively associated with power, agility, and balance, all of which help to improve sports-specific performance [2]. Conversely, young athletes who are not physically fit have a higher risk of injury, highlighting the protective function of systematic conditioning [3]. Rapid physiological, neuromuscular, and hormonal changes that occur during adolescence are a crucial developmental stage that have a big impact on how the body reacts to training stimuli. The body's ability to operate both aerobically and anaerobically is improved during this time by the development of the cardiovascular and respiratory systems, increases in bone mineral density, and growth in lean muscle mass [4]. When exposed to systematic training, the increased neuromuscular pathway plasticity promotes better improvements in motor abilities, strength, and coordination [5]. Moreover, Hypertrophy and metabolic efficiency are supported by hormonal fluctuations, namely high levels of growth hormone and testosterone [6]. However, to prevent overuse injuries and ensure long-term development, training loads must be properly controlled. Long-term benefits in performance, injury resilience, and general physical literacy can result from optimal programming during adolescence [7].

It is well recognised that the Body Mass Index (BMI), Resting Heart Rate (RHR), and Maximal Oxygen Consumption (VO_2 Max) are important indicators for assessing both overall health and sports performance. BMI provides information about weight-related health hazards and acts as an indirect indicator of body composition (WHO, 2020). Autonomic cardiac regulation is reflected in RHR, and lower values frequently signify improved cardiovascular efficiency [8]. The gold-standard measure of aerobic capacity and endurance potential is VO_2 Max, or the highest achievable rate of oxygen consumption during vigorous exercise [9]. Together, these metrics provide a comprehensive physiological profile that enables the assessment of athlete adaptations and the implementation of targeted training regimens, particularly during developmental phases such as adolescence. Rapid stretch-shortening cycle motions, or plyometric training, improve neuromuscular efficiency, explosive power, and elastic energy utilization—all of which are essential for young athletes to perform well in their particular activity [10]. Circuit training, on the other hand, combines strength and aerobic exercises sequentially, encouraging cardiovascular efficiency, muscular endurance, and metabolic changes that lower resting heart rate and improve body composition [11]. Optimizing aerobic capacity, cardiovascular health, and body mass index (BMI) for teenage athletes during this developmental stage promotes long-term well-being and competitive readiness [5]. By providing a variety of training stimuli, integrating different modalities may result in complementing physiological benefits that promote overall performance improvement and lower the risk of overuse problems.

Statement of the Problem

A little is known about the effects of circuit training and plyometric training separately and in combination on important physiological markers like body mass index (BMI), resting heart rate, and maximal oxygen uptake (VO_2

max) of adolescent athletes. Circuit training is known to improve cardiovascular fitness, muscular endurance, and body composition, while plyometric training is well known to increase explosive power through neuromuscular adaptations. Prior research has mostly looked at these modalities separately, ignoring any possible synergistic or unique adaptations that could arise from combining them. Thus, examining the relative and combined effects of circuit and plyometric training on these crucial characteristics may offer important information for creating comprehensive conditioning plans for adolescent athletes.

Objectives of the Study

1. To assess the effect of plyometric training on BMI, Resting Heart Rate, and VO_2 Max in adolescent athletes.
2. To assess the effect of circuit training on BMI, Resting Heart Rate, and VO_2 Max in adolescent athletes.
3. To assess the combined effect of plyometric and circuit training on BMI, Resting Heart Rate, and VO_2 Max in adolescent athletes.

Significance of the Study

For creating evidence-based conditioning programs, it is crucial to understand how plyometric and circuit training affect adolescent athletes' BMI, resting heart rate, and VO_2 max alone and in combination. Because of the quick physiological changes that occur in this age group, focused interventions are essential for maintaining a healthy body composition, improving cardiovascular health, and maximizing performance. The results of this study can help trainers and coaches create effective, age-appropriate training plans that optimize athletic potential and promote long-term health outcomes for young athletes.

Methodology

Research Design: The present study examines the individual and combined effects of plyometric and circuit training on body mass index (BMI), resting heart rate (RHR), and maximal oxygen uptake (VO_2 max) in adolescent athletes by using a pre- and post-test experimental design with four parallel groups. BMI, RHR, and VO_2 max, being the dependent variables, were evaluated before and after the intervention, whereas the kind of training intervention (Plyometric, Circuit, Combined Plyometric + Circuit, Control) was the independent variable.

Participants: Purposive sampling was used to select 120 adolescent athletes, ages 16 to 18, from sports academies (72 males and 48 females) of Assam. In addition to being free of cardiovascular disorders and participating in different competitive sports, participants had to be free of structured resistance or endurance training. Participants and their guardians provided informed consent.

Group Allocation: Participants were divided randomly into four equal groups of 30 athletes each. The Plyometric Training Group engaged in intense plyometric activities for the upper and lower bodies. To increase muscular endurance and aerobic fitness, the Circuit Training Group performed multi-station strength and cardiovascular conditioning circuits. To optimize complementary adaptations, the Combined Training Group engaged in a hybrid program that combined circuit and plyometric workouts in a single session. Without engaging in any further structured training intervention, the Control Group carried on with their usual routine sports practice.

Treatment: Over 2 weeks, there were three training sessions per week, each lasting 60 minutes. Bounding, hopping, depth leaps, and medicine ball throws were all part of the plyometric training, which increased in volume and intensity. Circuit training sessions included 8–10 stations that focused on main muscle groups and combined aerobic (skipping, shuttle sprints) and resistance (bodyweight, free weights) exercises. During the same session, the combined group switched between circuit and plyometric training on every alternate day. Every session started with 15 15-minute warm-up and ended with 10 minutes of cool-down exercises.

Instruments: BMI was determined by dividing body mass by height squared (kg/m²) using a calibrated stadiometer and digital weighing scale, while Resting Heart Rate (RHR) was measured with a validated digital heart rate monitor following a 10-minute seated rest. Maximal oxygen uptake (VO_2 max) was estimated using the multistage 20 m shuttle run test (Beep Test) following the Leger protocol. All assessments were conducted 24 hours before the training and repeated 24 hours after the final session to minimize the influence of acute exercise effects.

Statistical Analysis: All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 27.0. Descriptive statistics, including means and standard deviations, were computed for all dependent variables (BMI, RHR, and VO_2 Max) to summarize pre- and post-intervention values. Analysis of covariance (ANCOVA) was employed to compare post-test scores among the four groups while controlling for corresponding pre-test values. When significant main effects were detected, pairwise comparisons were conducted using the Least Significant Difference (LSD) post hoc test to identify differences between specific groups. Statistical significance was set at $p < 0.05$ for all analyses, and effect sizes were computed using partial eta squared (η^2) to assess the magnitude of observed effects.

Findings

Table 1: Descriptive Statistics (Mean ± SD) of BMI, RHR, VO_2 Max Across Groups.

Variable	Time Point	Plyometric (n=30)	Circuit (n=30)	Combined (n=30)	Control (n=30)
BMI (kg/m^2)	Pre-Test	21.19 ± 2.03	21.15 ± 1.67	20.92 ± 2.22	21.38 ± 2.18
	Post-Test	20.98 ± 2.10	20.81 ± 1.72	20.42 ± 2.27	21.31 ± 2.19
RHR ($beats/min^{-1}$)	Pre-Test	70.50 ± 5.52	69.27 ± 6.83	72.03 ± 5.51	69.93 ± 6.33
	Post-Test	67.03 ± 6.73	65.07 ± 7.03	66.20 ± 5.72	69.87 ± 7.33
VO_2 Max (ml/kg^{-1})	Pre-Test	44.47 ± 5.42	43.72 ± 7.91	42.92 ± 5.75	45.42 ± 6.41
	Post-Test	46.55 ± 5.66	47.11 ± 7.93	46.98 ± 5.84	45.57 ± 6.33

The mean BMI values for the Plyometric, Circuit, Combined, and Control groups were comparatively similar at baseline, ranging from 20.92 ± 2.22 kg/m² to 21.38 ± 2.18 kg/m², as shown in Table 1. All experimental groups experienced modest BMI decreases after the intervention, with the Combined training effect showing the largest relative decrease (20.42 ± 2.27 kg/m²) compared to the Control group, which experienced a slight shift (21.31 ± 2.19 kg/m²). Pre-test resting heart rate (RHR) ranged from 69.27 ± 6.83 to 72.03 ± 5.51 beats·min⁻¹. All training groups showed decreases after the test, with the Circuit training group (65.07 ± 7.03 beats·min⁻¹) and the Combined training group (66.20 ± 5.72 beats·min⁻¹) showing the largest decreases. Between 42.92 ± 5.75 ml·kg⁻¹·min⁻¹ and 45.42 ± 6.41 ml·kg⁻¹·min⁻¹, the VO_2 Max values prior to training varied. All experimental groups showed improvements after the intervention, but the Circuit training grew the most (47.11 ± 7.93 ml·kg⁻¹·min⁻¹), followed by the Combined training effect (46.98 ± 5.84 ml·kg⁻¹·min⁻¹) and Plyometric training (46.55 ± 5.66 ml·kg⁻¹·min⁻¹). The Control group showed little change.

To check whether the differences in the pre- and post-test in Table 1 are statistically significant or not at a 0.05 significance level, we will use ANCOVA (Analysis of Covariance) by controlling for the pre-test measures of BMI, RHR, and VO_2 Max across groups.

Table 2: Analysis of Covariance (ANCOVA) Table for BMI, RHR, and VO_2 Max Post-Test Scores After Controlling for Pre-Test Values

Dependent Variable	Source	Sum of Squares	df	Mean Square	F-Value	Sig.	Partial Eta Squared
BMI (kg/m²)	Group	3.068	3	1.023	14.523	<.001	.275
	Error	8.098	115	.070	-	-	-
RHR (bpm)	Group	80.761	2	40.280	4.159	.019	.088
	Error	834.893	86	9.708	-	-	-
VO_2 Max (ml/kg⁻¹)	Group	59.52	2	29.764	17.643	.001	.291
	Error	145.087	86	1.687	-	-	-

The ANCOVA results for post-test BMI, adjusted for pre-test values, revealed a statistically significant effect of the training intervention across the four groups ($F = 14.523$, $p < 0.001$, partial $\eta^2 = 0.275$). This indicates that the type of training program had a meaningful influence on BMI changes, even after controlling for baseline measurements. The effect size suggests a moderate to large proportion of variance in post-test BMI was attributable to group membership. Post hoc pairwise comparisons demonstrated that the Combined Training Group exhibited significantly greater reductions in BMI compared to both the Plyometric Training Group (mean difference = 0.297, $p < 0.001$) and the Circuit Training Group (mean difference = 0.167, $p = 0.016$). Moreover, the Combined Training Group also differed significantly from the Control Group (mean difference = 0.434, $p < 0.001$), reflecting the largest observed improvement among all comparisons. The Circuit Training Group showed a significantly greater reduction in BMI than the Control Group (mean difference = 0.267, $p < 0.001$), while the Plyometric Training Group also recorded a significantly greater reduction than the Control Group (mean difference = 0.138, $p = 0.047$). However, the BMI difference between the Plyometric and Circuit Training Groups did not reach statistical significance ($p = 0.061$).

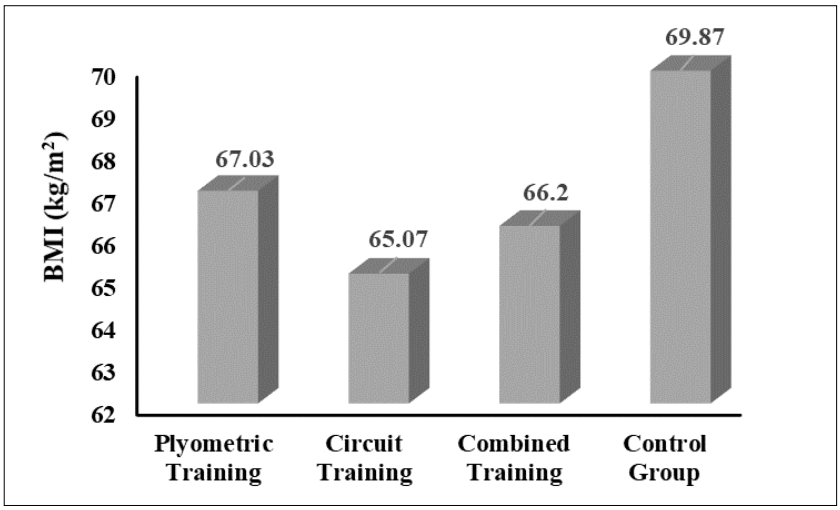

Fig 1: Graphical Representation of the Mean Value of Post-Test Measures of BMI Across Different Training Groups.

Again, ANCOVA was conducted to examine the effect of different training interventions on post-test Resting Heart Rate (RHR), while controlling for pre-test RHR values. The results revealed a statistically significant group effect on post-test RHR scores, $F(2, 86) = 4.159$, $p = 0.019$, with a partial eta squared of 0.088, indicating a small-to-moderate effect size. This suggests that the type of training intervention contributed meaningfully to variations in RHR outcomes after adjusting for baseline differences.

Post hoc pairwise comparisons of Post-Test RHR revealed that the Plyometric training demonstrated a significantly lower resting heart rate compared to the Combined training group (mean difference = –2.302 bpm, $p = 0.006$), indicating a more favourable cardiovascular adaptation following Plyometric training. No significant differences were observed between the Plyometric and Circuit training groups (mean difference = –1.188 bpm, $p = 0.333$) or between the Circuit and Combined training groups (mean

difference = –1.114 bpm, p = 0.067), although the latter approached statistical significance, suggesting a possible trend toward lower resting heart rate in the Circuit group relative to the Combined group. These findings suggest that while both Plyometric and Circuit training may confer cardiovascular benefits; Plyometric training appears particularly effective in reducing resting heart rate compared to a combined training approach.

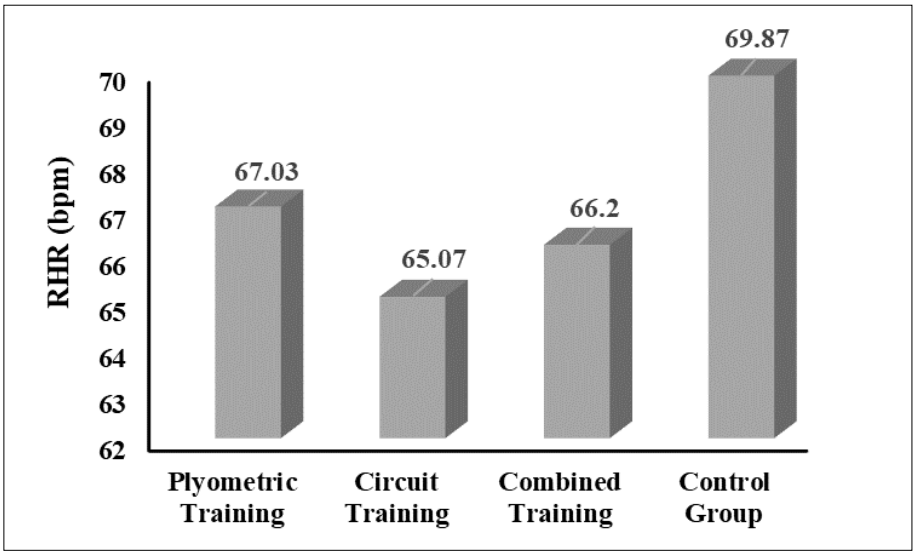

Fig 2: Graphical Representation of the Mean Value of Post-Test Measures of RHR Across Different Training Groups.

The ANCOVA for VO_2 Max, adjusted for pre-test scores, revealed a statistically significant difference among the training groups, F (2, 86) = 17.643, p = .001. The partial eta squared value of .291 indicates a large effect size, suggesting that the type of training intervention accounted for approximately 29.1% of the variance in post-test VO_2 Max scores.

Based on the pairwise comparisons, there are statistically significant differences in Post-Test VO_2 Max values between the groups. Specifically, the Plyometric Training group's mean Post-Test VO_2 Max is significantly lower than both the Circuit training group (mean difference = -1.301, p < 0.001) and the Combined training group (mean difference = -1.968, p < 0.001). Conversely, the difference between the Circuit and Combined training groups (mean difference = -0.667, p = 0.050) is only marginally significant, with the Combined group showing a slightly higher mean Post-Test VO_2 Max.

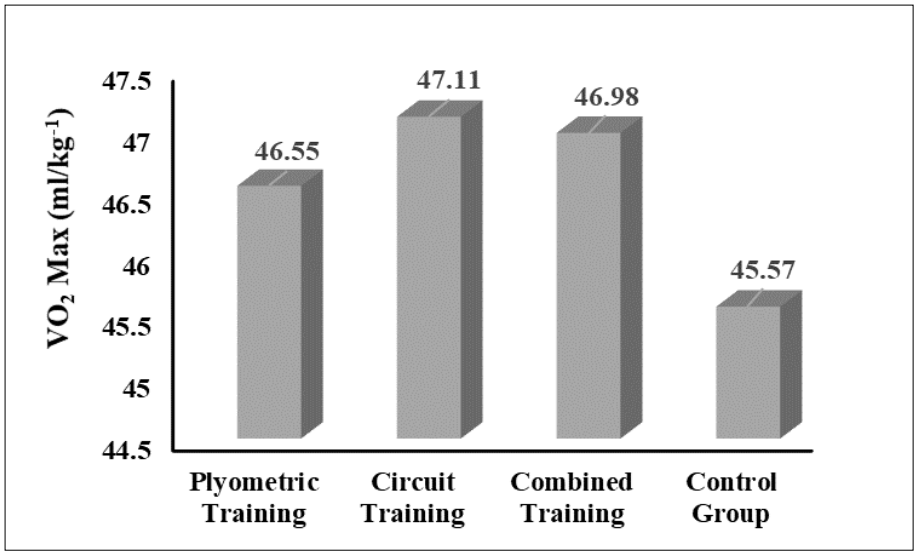

Fig 3: Graphical Representation of the Mean Value of Post-Test Measures of VO_2 Max Across Different Training Groups.

Discussion

The present study looked at how plyometric and circuit training affected adolescent athletes' BMI, resting heart rate (RHR), and VO_2 Max individually and in combination. The results showed that while all three training regimens resulted in noticeable physiological adaptations, the type and extent of these changes differed depending on the training modality. All experimental groups showed significant decreases in BMI when compared to the control, with the combined training (Plyometric*Circuit) effect showing the most noticeable decline. According to some studies, combining different training methods can enhance muscular strength, aerobic metabolism, and energy expenditure all at once, leading to synergistic effects on body composition [12, 13]. There was no statistically significant difference between the plyometric and circuit

groups; however, plyometric exercise alone led to a significantly larger reduction in RHR than combined training. Although both circuit and plyometric training can increase cardiac efficiency, the plyometric group's higher RHR decrease may be due to improved autonomic regulation and stroke volume from high-intensity, neuromuscular demanding exercises [14]. However, the lack of significant changes between circuit and combination training raises the possibility that the cardiovascular adaptations resulting from a single, targeted modality may be lessened when several training components are included in a single session.

Both the circuit and combination training groups performed better than plyometric training for VO_2 Max, with the combined group outperforming circuit training by a small but non-significant difference. Through repeated high-intensity bouts and prolonged cardiovascular strain, this study bolsters the proven significance of circuit-based protocols in improving aerobic capacity [15]. The combined group's increased neuromuscular stimulus from the plyometric component may have improved running economy and contributed to minor increases in VO_2 Max [10]. Given the increased brain plasticity, hormonal profiles, and flexibility of adolescents during this developmental stage, our findings are in line with research showing that multi-component training can be especially successful in this age group [4, 16].

Overall, the findings emphasize the importance of training specificity and program design for adolescent athletes. While combined training appears optimal for improving BMI and VO_2 Max, plyometric training may confer superior benefits for resting heart rate reduction. This suggests that targeted conditioning approaches may be preferable when the goal is to optimize specific physiological parameters. Future research should explore the longitudinal effects of these interventions, as well as their impact on sport-specific performance outcomes, to better inform evidence-based training recommendations.

Conclusion

As per this study, adolescent athletes who engaged in plyometric, circuit, and combined plyometric–circuit training experienced positive physiological changes; however, the benefits differed depending on the modality. The biggest BMI decrease was seen with combined exercise, suggesting synergistic advantages for body composition. Circuit and mixed training greatly outperformed plyometric training in increasing VO_2 Max, although plyometric training was most successful in reducing resting heart rate, indicating benefits for cardiovascular efficiency. These findings emphasize how crucial it is to choose training strategies according to certain performance objectives in order to maximize the growth and long-term health of young athletes.

References

1. Watson A, Brickson S, Brooks MA, Dunn W. Preseason Aerobic Fitness Predicts In-Season Injury and Illness in Female Youth Athletes. Orthopaedic Journal of Sports Medicine,2017:5(9).
2. Venckunas T, Mieziene B, Emeljanovas A. Aerobic Capacity Is Related to Multiple Other Aspects of Physical Fitness: A Study in a Large Sample of Lithuanian Schoolchildren. Frontiers in Physiology,2018:9(1).
3. Lloyd RS, Oliver JL, Faigenbaum AD, Howard R, De Ste Croix MBA, Williams CA, et al. Long-Term Athletic Development- Part 1. Journal of Strength and Conditioning Research,2015:29(5):1439–50.
4. Lloyd RS, Oliver JL. The Youth Physical Development Model. Strength and Conditioning Journal,2012:34(3):61–72.
5. Faigenbaum AD, Kraemer WJ, Cameron JRB, Jeffreys I, Micheli LJ, Nitka M, et al. Youth resistance training: Updated position statement paper from the national strength and conditioning association. Journal of Strength and Conditioning Research,2009:23(5):60–79.
6. Malina RM, Bouchard C, Or-Bar O. Growth, maturation, and physical activity. Human Kinetics, 2015.
7. Lloyd RS, Cronin JB, Faigenbaum AD, Haff GG, Howard R, Kraemer WJ, et al. National Strength and Conditioning Association Position Statement on Long-Term Athletic Development. Journal of Strength and Conditioning Research,2016:30(6):1491–509.
8. Fox EL, Bowers RW, Foss ML. The physiological basis for exercise and sport. McGraw-Hill Education, 2019.
9. Bassett DR, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Medicine and Science in Sports and Exercise,2000:32(1):70.
10. Markovic G, Mikulic P. Neuro-Musculoskeletal and Performance Adaptations to Lower-Extremity Plyometric Training. Sports Medicine,2010:40(10):859–95.
11. Alcaraz PE, Perez-Gomez J, Chavarrias M, Blazevich AJ. Similarity in Adaptations to High-Resistance Circuit vs. Traditional Strength Training in Resistance-Trained Men. Journal of Strength and Conditioning Research,2011:25(9):2519–27.
12. Sperlich B, Zinner CJ, Heilemann I, Kjendlie PL, Holmberg HC, Mester J. High-intensity interval training improves VO_2peak, maximal lactate accumulation, time trial and competition performance in 9–11-year-old swimmers. European Journal of Applied Physiology,2011:111(5):1029–36.
13. Faigenbaum AD, Kraemer WJ, Blimkie CJR, Jeffreys I, Micheli LJ, Nitka M, et al. Youth Resistance Training: Updated Position Statement Paper from the National Strength and Conditioning Association. Journal of Strength and Conditioning Research,2009:23(5):60–79.
14. Saez-Saez de Villarreal E, Requena B, Newton RU. Does plyometric training improve strength performance? A meta-analysis. Journal of Science and Medicine in Sport,2010:13(5):513–22.
15. Alcaraz PE, Sánchez-Lorente J, Blazevich AJ. Physical Performance and Cardiovascular Responses to an Acute Bout of Heavy Resistance Circuit Training versus Traditional Strength Training. Journal of Strength and Conditioning Research,2008:22(3):667–71.
16. Malina RM, Rogol AD, Cumming SP, Coelho e Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. British Journal of Sports Medicine,2015:49(13):852–9.